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Methods for Using Sensors to Trigger an Ambient Light Mode on a Foldable Smartphone

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Abstract:

This publication describes methods for using sensors to trigger an ambient light mode on a foldable smartphone. The sensors are configured to detect a folded state of the foldable smartphone (e.g., fully open, fully closed, in an intermediate position) and detect the orientation of the foldable smartphone (e.g., standing upright on a surface, lying on a surface). Responsive to the sensors detecting that the user of the foldable smartphone has oriented the foldable smartphone to stand upright, partially open on a surface, a Lighting Manager application implemented on the foldable smartphone triggers an ambient light mode on the foldable smartphone. The brightness may be adjusted according to how far open or closed the device is.

Keywords:

Foldable Smartphone, Ambient Light, Lighting, Two-Screen, Accelerometer, Display, Hall Sensor, Flex Sensor, User Interface, UI, Angle, Degree, Detection, Counter, Neural Network, Classifier.

Background:

Smartphone innovation has proceeded exponentially as manufacturers continue to find new ways to reimagine mobile technology. In that time, smartphone screens have faced a size constraint as a phone may only be so large before it no longer fits in the pocket of a user. To combat the desire for a larger screen with the same portability, smartphone manufacturers are developing foldable phones, some of which are already on the market. Foldable smartphones may include a hinge acting similar to a book spine, and a foldable screen that, when laid flat, has a large display that is comparable to the size of a tablet. While the main orientations of a foldable smartphone may include a fully folded “portable” configuration and an open flat “tablet” configuration, the device may also be used in unique ways when open partway at the various angles that the hinges allow. In one example, Mary props her smartphone against a few paperweights on her nightstand to use it as a reading light. She turns on the flashlight app, emitting a blinding, white light with limited dimming capabilities. As she angles the phone toward her book, it continues to slip down, never pointing at the right direction to illuminate her book and is too bright for the dark setting.

Description:

This publication describes methods for using sensors to trigger an ambient light mode on a foldable smartphone. A foldable smartphone includes a processor, sensors, a display, and computer-readable medium (CRM). In aspects, the sensors may include an accelerometer sensor that detects basic display orientations and a closed cover detection sensor (e.g., a Hall effect sensor or flex sensor).

Device data (e.g., user data, lighting preferences, counter preferences) is stored in the CRM. The device data may include instructions that, responsive to execution by the processor, cause the processor to perform operations of methods described in this publication, for example, a method for using sensors to trigger an ambient light mode on a foldable smartphone. In aspects, the operations may include implementing a fold pattern recognition algorithm that utilizes sensor data relating to a folded state of the foldable smartphone and the orientation of the foldable smartphone to trigger an ambient light mode.

The operations may further include determining a consecutive classification of the event of interest using a detection counter algorithm, publishing the final event to the appropriate user interface (UI), using closed cover detection sensor to discriminate between many fold angles, and determining a screen brightness directly proportional to the closed cover detection sensor proximity value.

In aspects, the device data includes executable instructions of a Lighting Manager application that causes the foldable mobile device to perform the operations described in this publication.

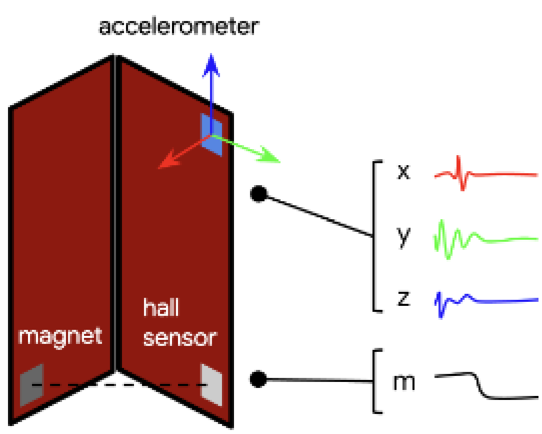

Figure 1: Foldable Mobile Device

Figure 1 illustrates an example of a foldable smartphone implementing a method for using sensors to trigger an ambient light mode. The foldable smartphone may include an outside display (not illustrated), a foldable inside display, and a hinge in the center of the device. The foldable smartphone includes at least one closed cover detection sensor configured to detect the proximity between one side of the display and the other and generate a signal (m) representing that distance. In an aspect, the closed cover detection sensor is a Hall effect sensor configured to detect the distance between opposite sides of the foldable device and generate the signal based on the proximity of the sensor to a magnet. In another aspect, the closed cover detection sensor is a flex sensor configured to detect the distance between opposite sides of the foldable device and generate the signal based on how far the device is folding. The foldable smartphone of Figure 1 further includes an orientation sensor (e.g., an accelerometer) configured to detect the orientation of the device. The orientation sensor records orientation in the three cartesian coordinates, x, y, and z, which may define whether the device is in the correct orientation to trigger the Lighting Manager application. The closed cover detection sensor (e.g., a Hall effect sensor, flex sensor) records a proximity value, m, focusing the Lighting Manager application on four dimensions, x, y, z, and m.

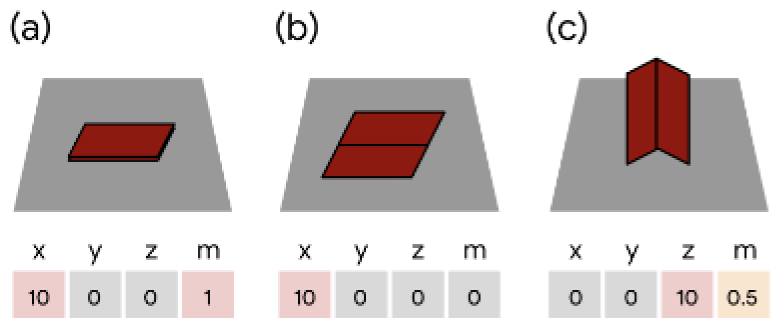

Figure 2: Placement Scenario Examples

Figure 2 illustrates three examples (example (a), example (b), and example (c)), which illustrate how the readings of x, y, z, and m may vary over many placement scenarios of foldable smartphones resting on a surface (e.g., a table). Example (a) illustrates that a closed foldable smartphone on the table would generate a signal with a high closed cover detection sensor proximity value, while one of the accelerometer readings aligns with gravity (axis x). In example (b), for an open foldable smartphone, the accelerometer-gravity alignment stays the same, but the closed cover detection sensor reading drops to a low value. In example (c), the accelerometer axis that points to the uprightness (axis z) spikes, and the closed cover detection sensor reading is moderately high.

These three examples of foldable smartphone orientations demonstrate how the x, y, z, and m signal spaces have enough variability over typical placement scenarios that it is possible to discern the foldable smartphone upright ("docked") on a table from other natural placement scenarios (e.g., held straight up for an extended period of time by the user, leaning almost vertically against a surface, and the like).

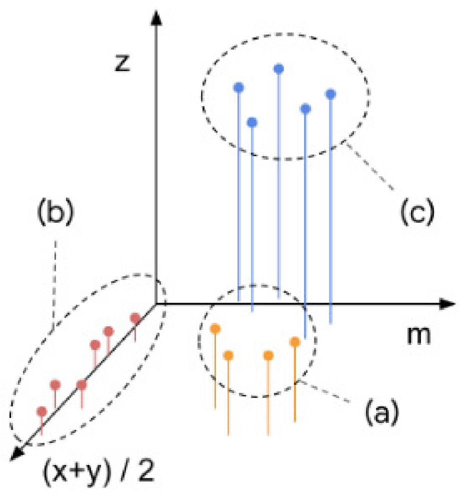

Figure 3: Placement Scenario Detection Plot

The discernment of the foldable smartphone between different placement scenarios may be visualized using the plot illustrated in Figure 3, above, with reference to the measurements of Figure 2. To visualize a 4-dimensional feature in a 3-dimensional space, the x-axis and y-axis readings illustrated in Figure 3 are averaged, as they contain null information not being used by the sensors for the case of methods for using sensors to trigger an ambient light mode on foldable smartphones. In Figure 3, a cluster of points for (c) is separated from (a), (b), and many natural placement scenarios that happen in the real world.

Measurements of x, y, and z, representing the orientation state of the foldable smartphone and measurements of its closed cover detection, m, can be collected and categorized with corresponding device states to train the ML model to trigger the Lighting Manager Application in those designated states. After sufficient training, the ML model can be deployed to the CRM. In aspects, the ML model may be a fully connected neural network-based model with corresponding layers required for processing input features.

Referring to Figure 4, the ML model is trained to classify sensor detection information to determine the orientation and proximity of the two sides of the device and generate predictions for user intention that are used by the Lighting Module operating system of the computing device to trigger the Lighting Manager Application. Each reading of the four-number vector (e.g., x, y, z, m) may be fully connected to a neural network which outputs a decision that is either 0 or 1. In this case, 0 indicates readings that do not describe a full light orientation, and 1 indicates results of the readings that describe an orientation where the lighting application is triggered, the “Trigger Fold-and-Go” feature of Figure 4. When feature separation is confirmed by the device, a classifier stack that automates the detection may be built, as outlined in Figure 4, below.

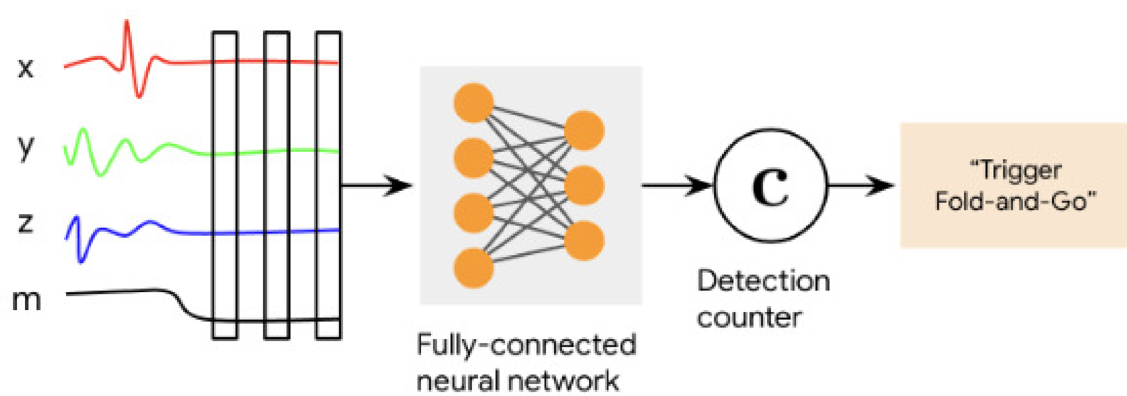

Figure 4: Ambient Light Mode Detection

An example method for using sensors to trigger an ambient light mode on foldable smartphone includes several operations. In a first operation, the accelerometer and closed cover detection sensor(s) detect the orientation and closed proximity of the device and read it into a four-number vector reading (e.g., x, y, z, m). In a second operation, a machine-learned model receives the four-number vector as an input reading and generates a prediction regarding the orientation and folded state of the foldable smartphone. In a third operation, a detection counter with a predesignated timer detects how long the device was in each orientation and/or proximity. In a fourth operation, responsive to determining that the foldable smartphone in a particular orientation and folded state suitable for the utilization of an ambient light mode (e.g., the device standing upright and partially open on a surface) for the predetermined amount of time, the Lighting Manager application triggers an ambient light mode.

The detection counter may be utilized to differentiate between a transient event where the user coincidentally put the foldable smartphone in the orientation for the lighting application to start and moved the foldable smartphone right away, not intending to trigger the ambient light mode, and when the intent of the user is to trigger the ambient light mode. In an example, the user may configure (e.g., by the Lighting Manager application) the detection counter to start after ten seconds of the foldable smartphone being in the upright, folded position. If the foldable smartphone is moved again before that time, then the counter stops, and the ambient light mode is not triggered. This extra gating factor keeps the ambient light mode from being falsely triggered.

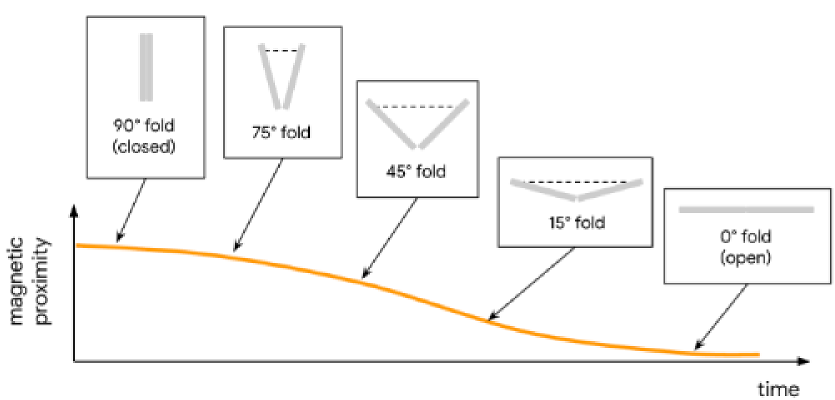

Figure 5: Magnetic Proximity Versus Time Plot

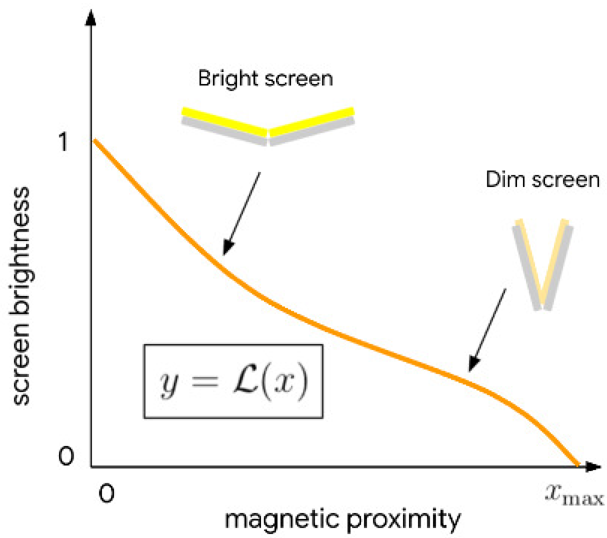

Figure 6: Screen Brightness Versus Magnetic Proximity Plot

Furthermore, as illustrated in Figures 5 and 6, above, the Lighting Manager application may adjust the screen brightness depending on the closed cover detection sensor's reading. Figure 5 shows it is possible to discriminate between many fold angles, which can then guide the exact illumination brightness for ambient use cases as illustrated further in Figure 6.

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